DIAGNOSTICS AND MODELING OF DIAMOND DEPOSITION PLASMAS DISCHARGES UNDER PULSED MODE

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I. Introduction

In this paper we present experimental and theoretical investigations of moderate-pressure H_2 and H_2/CH_4 plasmas operating under pulsed mode. These plasmas are processed under discharge conditions usually adopted for diamond deposition experiment, i. e. pressure in the range 10 - 200 mbar and input microwave power between 1 and 4 kW for a 2.45 GHz excitation microwave. The plasma is activated in a quartz bell-jar reactor. The use of pulsed mode is motivated by the possibility to increase the growth rate and quality of diamond. Indeed, previous studies have shown that pulsed plasma allow to optimize the concentration of active species, in particular H-atom [1, 2, 3].

II. Model Overview

A thermo-chemical model was developed to predict the time-variations of species concentration and plasma temperature in the plasma of interest. The model is based on the solution of the electron Boltzmann equation coupled to the species kinetics equations and a total energy equation that gives the gas temperature. The results were then interpreted in term of the effect of discharge mode on diamond growth rate and quality.

Time-resolved gas temperature measurements have been performed in a bell-jar reactor on H_α line (656,3 nm), while time-variation of the plasma volume during the discharge pulse has been investigated using a "Flashcam" that enables a 1 µs time resolution.

III. Results

The results show that the steady state value of the gas temperature is reached 1 ms after the beginning of the pulse (with a heating rate of 12 $K.\mu s^{-1}$). On the other hand, Flashcam measurements show that the volume of the discharge remains fairly small during the first 500 µs of the pulse. Thus, the power density is very high during the first 250 µs of the pulse, due to the fact that the in-pulse value of microwave power absorbed by the plasma is achieved after only 30 µs, while the volume of the discharge is small. As a result the absorbed microwave power density, and therefore the gas temperature, is very high during the first stage of the discharge. Of course, the absorbed power density rapidly decreases for time greater than 250 µs, due to the expansion of the discharge. This effect was taken into account in the thermo-chemical model which was then used to simulate the discharge studied in this work.

Furthermore, variations of the steady state gas temperature as well as of the substrate and wall temperatures as a function of the pulse cyclic ratio (α = plasma duration / period) has been measured : gas temperatures identical to that obtained in the continuous mode have been obtained while the substrate and wall temperature are considerably reduced. Then, pulse regime allows one to work at very high power density (necessary for high dissociation rate of molecular hydrogen) keeping enough low the substrate temperature and energy loss through the reactor walls.

References

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